Coastal flood protection management under uncertainty – the Danish case

Jumppanen Andersen, Kaija; Sørensen, Carlo Sass; Piontkowitz, Thorsten

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Coastal flood protection management under uncertainty – the Danish case

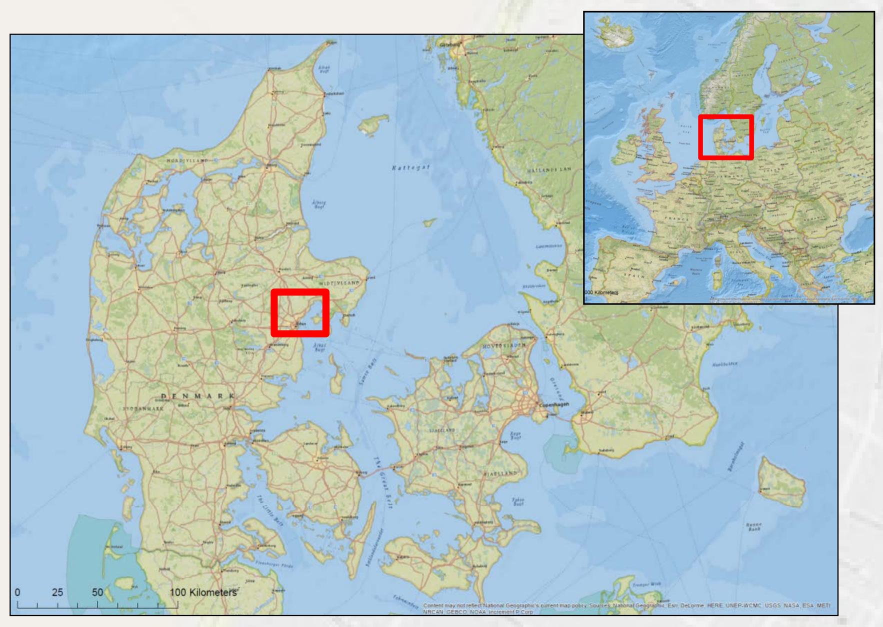

Figure 1: Location of Aarhus in Denmark and surrounding waters.

LOCAL STAKEHOLDERS RESPONSIBILE FOR COASTAL MANAGEMENT

In Denmark, the responsibility of defining, planning and implementing coastal flood protection lies with the local stakeholders, such as landowners and municipalities. Similarly, it is a municipal responsibility to define building foundation and flood protection levels in urban planning and long term development. These planning and protection levels are most often defined from the hazard instead of a risk perspective.

The Danish Coastal Authority (DCA) guides local stakeholders on general coastal flood protection and implements the EU Flood Directive on flood risk reduction in appointed areas of significant flood risk. DCA is obligated to communicate the concept of risk and, in a thorough and easily comprehendible way, the hazards and uncertainties relating to this today and in the future.

PLANNING FROM THE PERSPECTIVE OF THE HAZARD – BUT STILL NOT ENLIGHTENED

Denmark has a diverse coast with exposed coastlines, straits, fiords etc. Storm surges and extreme sea levels vary therefore significantly across the country. More than 80 tide gauge stations and extreme statistic from 68 stations are used to report and assess extreme sea levels (figure 2, left). Local communities normally use the maximum water level from a recent event or the level of a statistical 100 years event as the basis when deciding upon design level. As Denmark experiences land uplift (figure 2, right), a value representing this is usually included together with a single number representing sea level rise (SLR) due to climate change.

SLR is acknowledged as the most significant single contributor among several potential sources to changes in the future storm surge heights. By inclusion of just a single number for SLR (often 30 cm for 2050 and 60-80 cm by 2100), there is no reflection in the municipalities of what this number represent or conceals, or how SLR will affect the flood hazard.

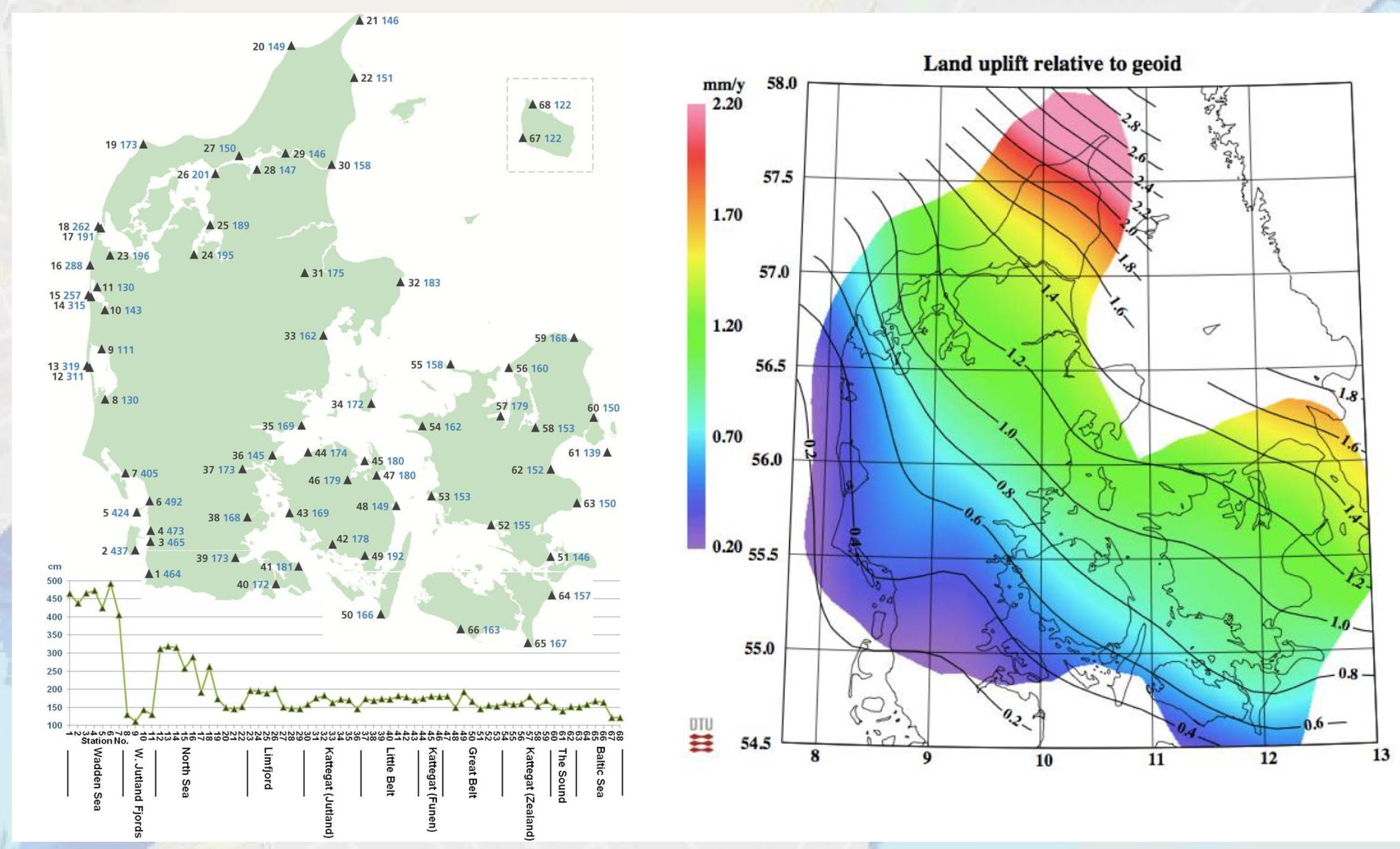

Figure 2: (left) 100 yr return heights (in blue) in cm above datum (DVR90) for 68 of the Danish water gauge stations (Sorensen et al., 2013), and (right) uplift rates in Denmark (Knudsen et al., 2016)

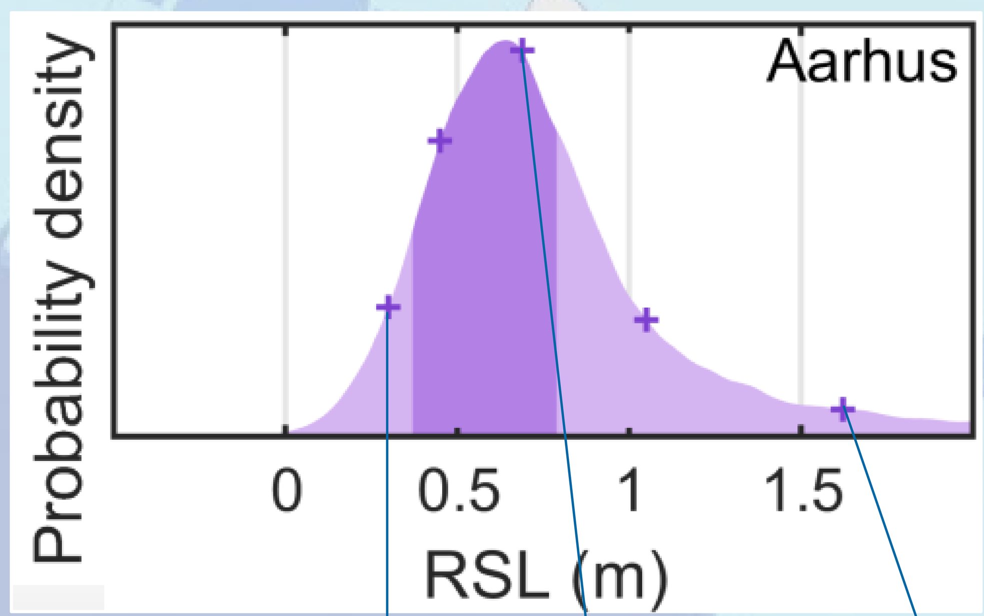

Figure 3: Projected regional SLR over the 21st century and uncertainty distribution for Aarhus, Denmark under RCP8.5, The 5th, 17th, 50th, 83rd and 95th percentiles are marked with crosses (Grinsted et al. 2015)

FLOOD EXTENT VARIABILITY IN AARHUS

Grinsted et al. (2015) present probability distributions for SLR projections for northern Europe under IPCC scenario RCP8.5, and their work presents local SLR projections for three Danish locations, including Aarhus (figure 3).

An urban area of Aarhus has previously experienced flooding and is protected by a 2 m high dike. If considering a 100 years return water level and add SLR for the 5th, 50th and 95th percentiles, the inundated area varies significantly (figure 4). The floods primarily affect the expensive residential areas with an increase from 2,649 to 9,119 buildings becoming flooded between the 5th and 95th percentiles (table 1).

Table 1: SLR, heights of a 100 years event, and number of flooded buildings in case area for three SLR projections.

SLR Pro-jection	SLR by 2100	Water level of 100 yr return period (1.62 m)	Number of buildings flooded
5%	0.30 m	1.92 m	2,649
50%	0.69 m	2.31 m	4,886
95%	1.62 m	3.24 m	9,119

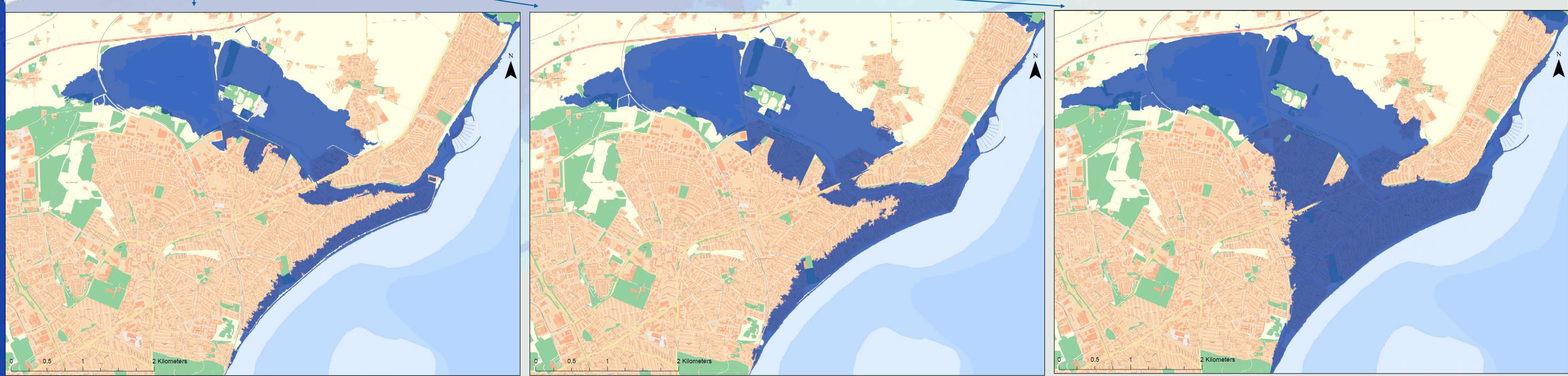

Figure 4: Flood extent in an Aarhus suburb of a 100 years event and 5% (left), 50% (middle) and 95% (right) local SLR projection by 2100 under RCP8.5.

BETTER UNDERSTANDING OF HAZARD VARIABILITY IMPROVES LONG-TERM RISK PLANNING

From the above example it gets clear, that the uncertainty in the hazard can have enormous consequences, which are not dealt with, due to the lack of awareness regarding uncertainties.

Figure 5 illustrates the probability of certain extreme water levels from extreme statistics today and the probability of SLR by 2100. Dark blue colours represent more probable sea level than white. The line represents a SL of 2.3 m, which is considerably above a 1000 years event today, and illustrates how SL may vary between a 10 and a 1000 years event, depending on the SLR by 2100.

Compared to a single number describing future SLR, the figure aims at creating a better understanding of the variability in hazards; the relationship between return periods and SLR, and how the variability of one affects the other. From this stakeholders will better understand future variations in the hazard and incorporate these in long-term coastal and risk management plans. An improved understanding of the potential variabilities in future hazards will help both decision-makers who plan from risk analyses or from the perspective of the hazards only.

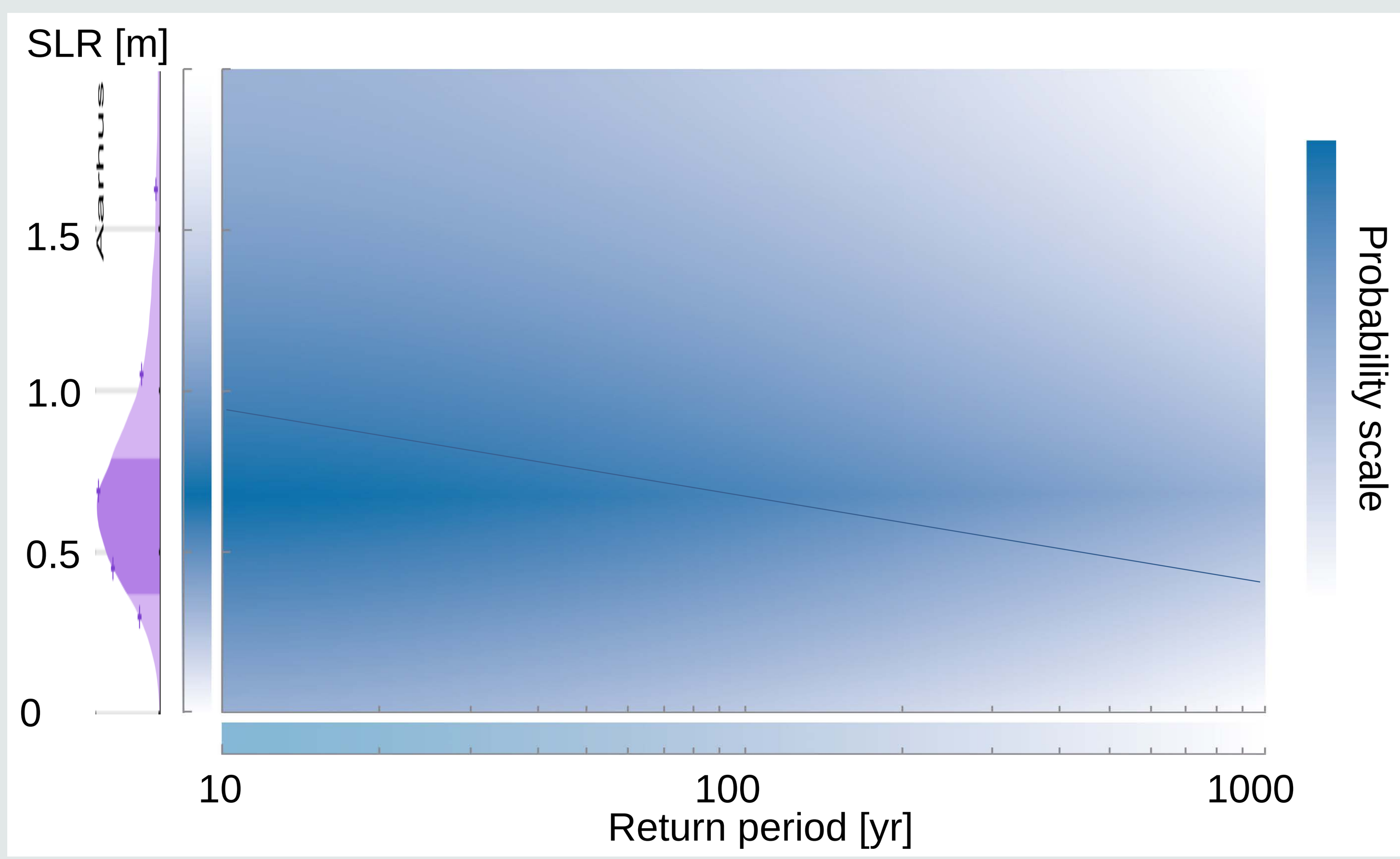

Figure 5: Probability of extreme water levels from extreme statistics vs. probability of sea level rise by 2100, RCP8.5. Dark blue colours represent more probable sea level than white. The line represents a sea level of 2.3 m.

Ministry of Environment and Food of Denmark
Coastal Authority

DTU

Kaija Jumppanen Andersen (kja@kyst.dk), Carlo Sørensen (carlos@space.dtu.dk) & Thorsten Piontkowitz (tpi@kyst.dk)